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Analysis of the relationship between start of the rainy season and farmer's sowing date in the Niamey area and its impacts on the pearl millet yield

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CONTEXT

In semi-arid agro-systems of Sahelian West Africa, where economy and food security is highly sensitive to climate variability, timing and quality of the monsoon rainfall have a critical importance to agricultural planning (Ingram et al., 2002). As in the most of Sahelian countries, more than 90% of population of Niger is rural and the principal source of livelihood is subsistence rain-fed agriculture. Pearl millet [Pennisetum glaucum (L) R. Br.] is the main staple food (~ 75% of the national total production) and is entirely produced under rain-fed conditions in traditional farming systems that use low off-farm input (Amadou et al., 1999, FAOSTAT date, 2005; Soler et al., 2008). The low productivity of the crop in traditional environments and its high variability, combined with the population's rapid growth, is the principle cause of vulnerability of the populations which suffers from recurrent food crises.

Moreover, sowing represents the first important farming operation during crop calendar and assumes a crucial stake for crop establishment. According to Milleville (1998), sowing date is an essential factor for harvest because a bad timing implies low production.

AIMS

- **To document the farmer's sowing strategy and its link with the local-scale rainfall**
- **To analyze the relationship between sowing date and start of the rainy season at different spatial scales**
- **To investigate the link between sowing date and pearl millet yield**

STUDY AREA and DATASETS

AMMA-CATCH Niger meso-scale site

- located at the center of Sahel in SW Niger
- area ~16 000km² (1.6°E-3.3°E / 13°N-14°)
- rainfall between XX mm and XX mm

2 High resolution Datasets

• Daily rainfall records
- 30 rain-gauges network *(blue points)*
- 1990-2008 period
- April 15 to October 15
- ~30 km between stations
- ~ 6% of missing entries

• On-Farm survey: agronomic details
- 10 experimental sites – 2004-2007 period *(black circles)*
- 30 farmers' plots documented technical itinerary :
  - ♦**Sowing/re-sowing date – harvest date**
  - ♦**Cultivars (HK or SOMNO)**
  - ♦**Phenology of crop**
  - ♦ **Soil properties** (depth, type)
  - ♦ **Off-farm input** (fertilizer, kind of fertilizer)
  - ♦ **Biomass and yields** (kg/ha)

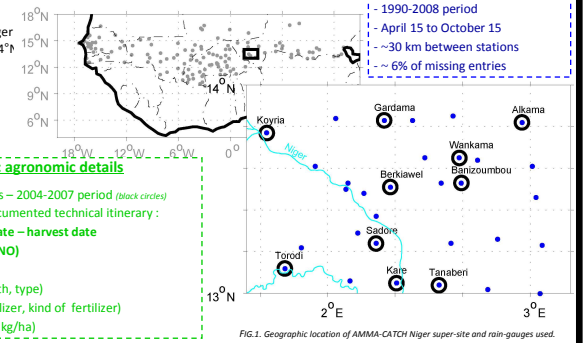

FIG.1. Geographic location of AMMA-CATCH Niger super-site and rain-gauges used.

SARRA-H crop model

SARRA-H is a simple, deterministic crop model for cereals, based on the water balance model operating at daily time steps and implemented on Ecotrop platform of CIRAD (Dingkuhn *et al.* 2003). SARRA-H simulates attainable yields at the plant population scale. 3 types of processes are simulated : (i) soil water dynamic, (ii) phenology and carbon assimilation and (iii) plant water use and drought simulation.

RESULTS

1. Occurrence of the sowing date

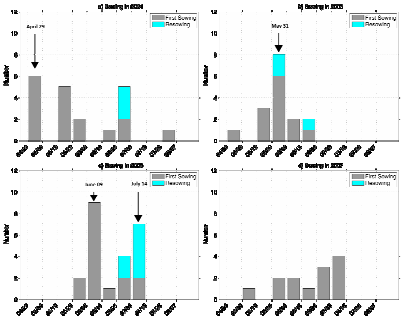

FIG.2. Distribution of sowing date occurrence (first sowing & re-sowing) for each year during 2004-2007 period.

- Sowing period spreads over 3 months between May and July
- 1 to 2 waves of sowing per year (sowing wave = 6 occurrences of sowing date during the same 10-day period)
- Sowing wave occurs April 29, 2004 ; May 31, 2005 and June 09, 2006 in 2007 any sowing wave is detected

2. Successful vs failed sowing: effect of rainfall distribution and water stress

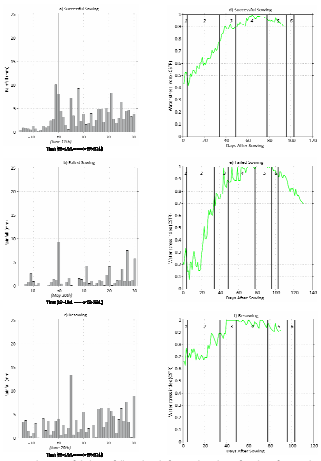

FIG.3. Composite diagram of daily rainfall 15-days before and 30-days after the reference date (t0) indicating sowing date for (a) successful sowing date, (b) failed sowing date, (c) resowing date and water stress index (CSTR) from (d) successful sowing date, (e) failed sowing date and (f) resowing. Italic values indicate the 6 keys phenological stage of mean growth duration of pearl millet.

- 23% of sowing have failed during the 2004-2007 period
- Sucessful sowing are systematically caused by wet sequence over 2-days receiving about 20 mm
- Failed sowings are linked to isolated rainfall of « pre-season » of low intensity (recording less than 10 mm) and followed by a long dry spell (> 10-day) causing water deficit (CSTR) during emergence stage and basic vegetative period
- Re-sowing date occurs latter during the monsoon period

3. Link between sowing date and start of rainy season

❖ *Interannual variability*

2 groups of methods used to defined the start of rainy season :

☛ ***Local scale Agro-climatic definitions***
- Kowal and Knabe (1972)
- Benoit (1977)
- **Sivakumar (1988) : onset date = first day of wet spell of 3 consecutive days receiving at least 20 mm without any 10-day dry spell during the following 30 days from onset date (avoiding « false start »).**
- Ati et al. (2002)
- Marteau et al. (2009)

☛ ***Large and meso- scale climatic définitions***
- Sultan and Janicot (2002)
- **Balme et al. (2005) : onset date = the first spell of two consecutive days recording at least one day exceeding 'x' mm for 90% of stations in a radius of 300km.**

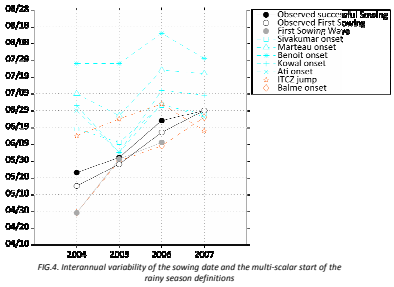

FIG.4. Interannual variability of the sowing date and the multi-scalar start of the rainy season definitions

- Local-scale agronomic onset date appears not concomittant with the observed sowing date excepted Sivakumar criterion
- First sowing date seems rather close to « meso-scale Balme start of rainy season »

❖*Correspondance between sowing date and agronomic start of rainy season*

	Sowing *before* « onset »	Sowing *during* « onset »	Sowing *after* « onset »
Balme	13 %	46 %	41 %
Sivakumar	41 %	46 %	13 %
Kowal	46 %	38 %	16 %
Ati	57 %	30 %	13 %
Marteau	81 %	16 %	3 %
Benoit	100 %	-	-

Tab.1. Distribution of successful sowing date in relation to start of the rainy season.

- About 50% of sowing dates are concomittant with Balme onset and Sivakumar onset
- Sowing period is limited between Balme onset date and Sivakumar onset date → 87% of sowing are done after Balme onset (earlier) and 87% before Sivakumar onset (latter)
- Sowing is generally done in advance at the beginning of the rainy season

❖ *Synchronization between meso-scale convective system and first sowing waves*

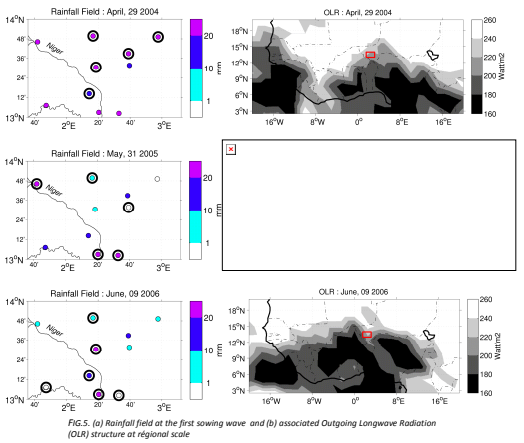

FIG.5. (a) Rainfall field at the first sowing wave and (b) associated Outgoing Longwave Radiation (OLR) structure at régional scale

- First sowing wave is phasing with the meso-scale « Balme » onset and OLR fields present large structures of atmospheric convection
- Spatial coherence of the sowing date is in relation with spatial homogeneity of the rainfall field

4. Sensitivity of simulated pearl millet yield to sowing date…

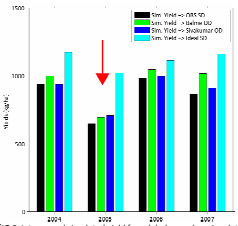

FIG.6. Interannual simulated yield from (a) observed sowing date (b) Balme onset, (c) Sivakumar onset and (d) Ideal sowing date

- Forcing sowing date in SARRA-H crop model shows a low impact on simulated grain yield → sow at onset date does not improve yield
- In 2005, model simulate systematically a low yield whatever the sowing date

… and intra-seasonal dry spell in 2005

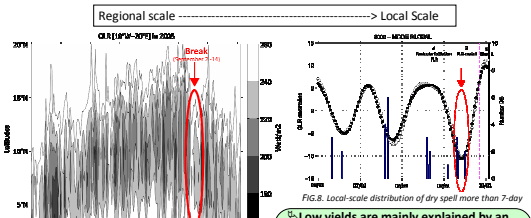

FIG.7. Time-Latitude diagram from April 1st to October 31th 2005 of unfiltered OLR averaged 10 °W-20 °E.

FIG.8. Local-scale distribution of dry spell more than 7-day

- Low yields are mainly explained by an extended dry sequence over West Africa (weakening of convection)… at local-scale 80% of villages record synchronous dry spell (> 7-day) during critical phenologic stage of flowering (*FLR-matu1*).

CONCLUSION

At the scale of the AMMA-CATCH Niger supersite, farmer's sowing strategy shows that:

- **Sowing date coincides with a rainy day receiving at least 10 mm most of the time in advance of the effective start of the rainy season**
- **Local-scale agronomic onset date does not correspond to the observed sowing date**
- **Sowing date is mainly governed by the extended « mesoscale » convective rainfall event giving a spatial coherence to sowing date**
- **Sowing date seems to have a little impact on the grain yield contrary to intra-seasonal dry spell during critical phenologic stage.**

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